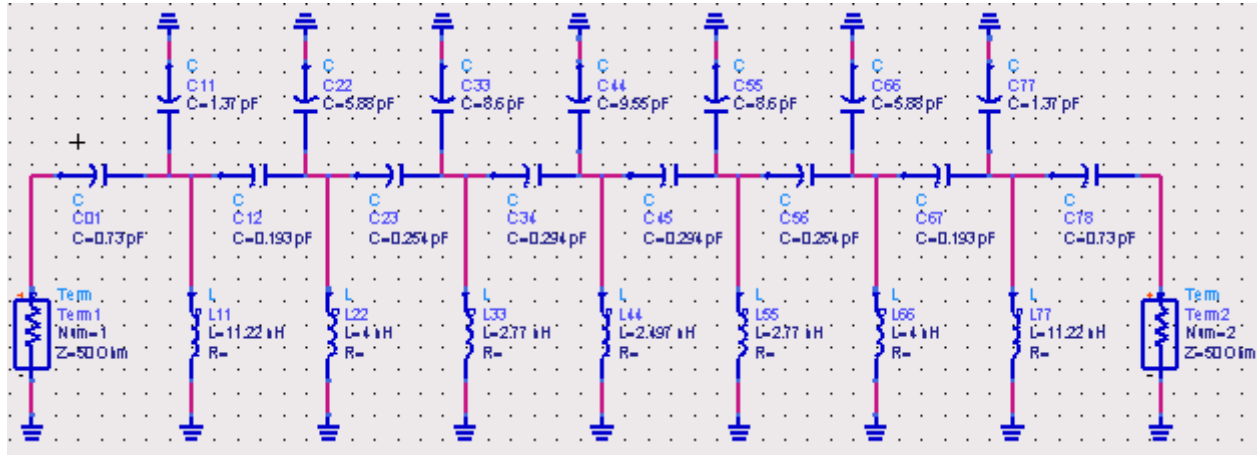


Capacitively Coupled Chebychev BPF

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This sheet is used to design a **microwave capacitively coupled BPF**. The maths for this filter is modified from "Theory & Design of Microwave Filters", Ian Hunter, IEE Press.

The schematic that is designed and simulated is shown above for N=7, BW=50MHz, 30dB return loss.

Main user input area:

$$\mu\text{m} := 10^{-6} \cdot \text{m} \quad \text{nH} := 10^{-9} \cdot \text{henry}$$

$L_{\text{ar_db}} := 30$ Passband return loss in dB

$N := 7$ Order of the filter, this needs to be above 2 and even numbers.

$f_{\text{gm}} := 1 \cdot \text{GHz}$ $Z_0 := 50 \cdot \Omega$ $\text{bandwidth} := 50 \cdot \text{MHz}$

Start Calculating...

$$f_{\text{low}} := f_{\text{gm}} - \frac{\text{bandwidth}}{2} \quad f_{\text{high}} := f_{\text{gm}} + \frac{\text{bandwidth}}{2} \quad \text{bw} := \frac{f_{\text{high}} - f_{\text{low}}}{f_{\text{gm}}}$$

$$f_{\text{bp}}(f) := \frac{1}{\text{bw}} \cdot \left(\frac{f}{f_{\text{gm}}} - \frac{f_{\text{gm}}}{f} \right) \cdot f_{\text{gm}} \quad \text{bwpercent} := \text{bw} \cdot 100 \quad \mathbf{a} := \frac{f_{\text{gm}}}{\text{bandwidth}}$$

bwpercent = 5

$\mathbf{a} = 20$

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev BPF

$$Y_o := \frac{1}{Z_0} \cdot \mathbf{e} := \left(10^{\frac{L_{\text{ar_db}}}{10}} - 1 \right)^{-0.5}$$

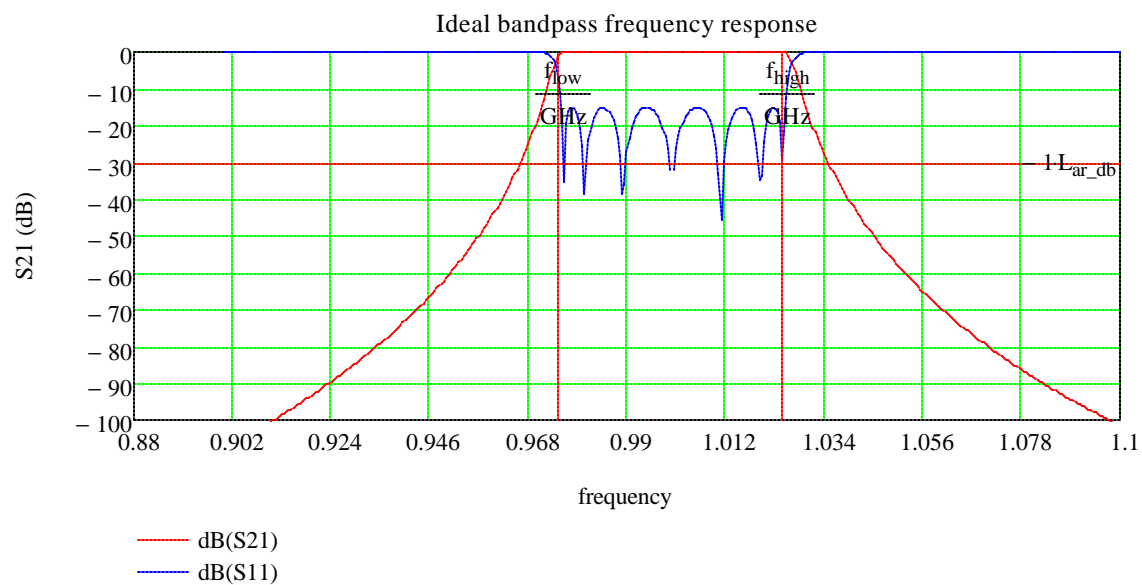
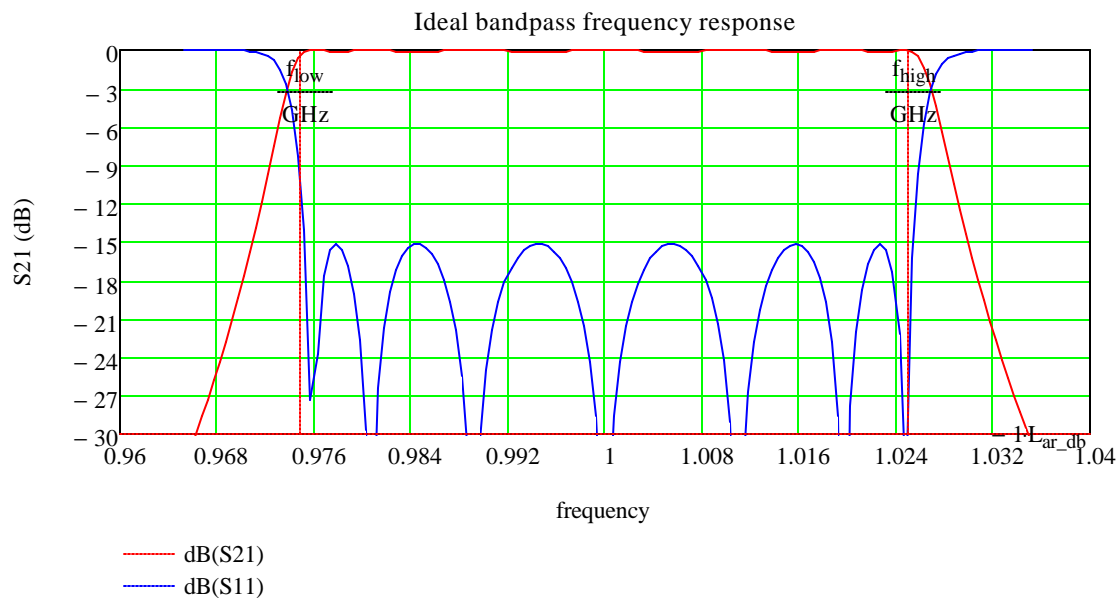
$\mathbf{e} = 0.03164$

$$L_A(f, f_c) := \begin{cases} 10 \cdot \log \left[1 + e \cdot \left(\cos \left(N \cdot \arccos \left(\frac{f}{f_c} \right) \right) \right)^2 \right] & \text{if } f \leq f_c \\ 10 \cdot \log \left[1 + e \cdot \left(\cosh \left(N \cdot \operatorname{acosh} \left(\frac{f}{f_c} \right) \right) \right)^2 \right] & \text{if } f > f_c \end{cases}$$

$$S11_A(f, f_1) := 10 \cdot \log \left[1 - 10^{\left(\frac{-L_A(f, f_1)}{10} \right)} \right]$$

$$f_{\text{bp_narrow}} := 0.99 \cdot f_{\text{low}}, \frac{f_{\text{high}} - f_{\text{low}}}{100} + 0.99 \cdot f_{\text{low}} .. 1.01 \cdot f_{\text{high}}$$

$$f_{\text{bp_wide}} := (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}), (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}) + \frac{f_{\text{gm}} \cdot \text{bw}}{100} .. f_{\text{gm}} + (2 \cdot f_{\text{gm}} \cdot \text{bw})$$



Calculate the circuit values.....

$$? := \sinh\left(\frac{1}{N} \cdot \operatorname{asinh}\left(\frac{1}{e}\right)\right)$$

$$n := 1, 2..N$$

$$nn := 1, 2..N - 1$$

$$nnn := 0, 1..N$$

$$K_{nn, nnn+1} := \frac{\left[?^2 + \left(\sin\left(\frac{nn \cdot \mathbf{p}}{N}\right)\right)^2\right]^{0.5}}{?}$$

$$C_{nn} := \frac{2}{?} \sin\left[\frac{(2 \cdot n - 1) \cdot \mathbf{p}}{2 \cdot N}\right]$$

$$Cap_{0,1} := \frac{1}{\left[2 \cdot \mathbf{p} \cdot f_{gm} \cdot (\mathbf{a} - 1)^{0.5} \cdot Z_o\right]}$$

$$Cap_{N,N+1} := \frac{1}{\left[2 \cdot \mathbf{p} \cdot f_{gm} \cdot (\mathbf{a} - 1)^{0.5} \cdot Z_o\right]}$$

$$Cap_{0,1} = 0.730 \cdot \text{pF}$$

$$Ind_{n,n} := \frac{Z_o}{C_n \cdot 2 \cdot \mathbf{p} \cdot f_{gm}}$$

$$Cap_{nn, nnn+1} := \frac{K_{nn, nnn+1}}{\mathbf{a} \cdot 2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o}$$

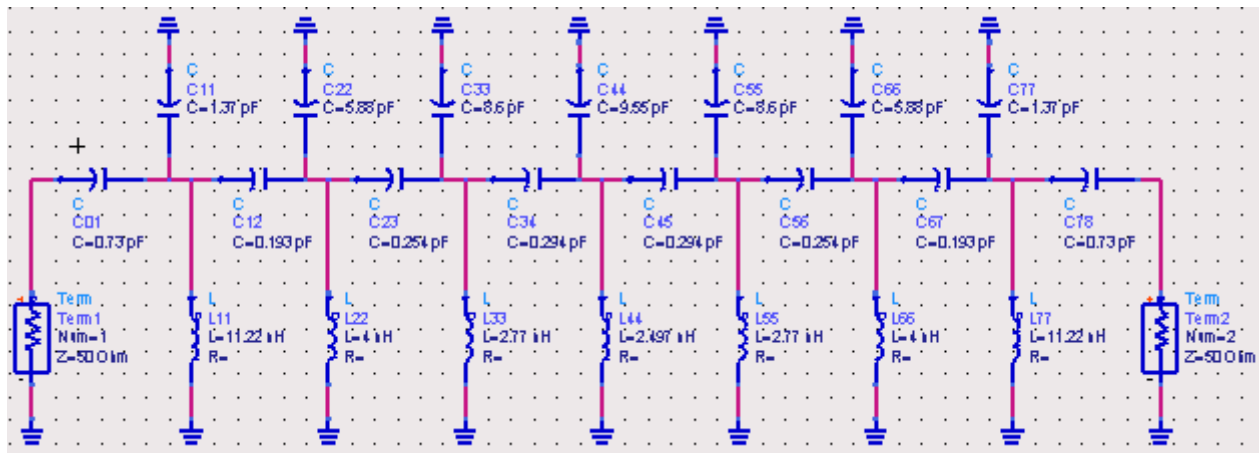
$$Cap_{n,n} := \frac{C_n}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o} - Cap_{n-1,n} - Cap_{n,n+1}$$

$$Cap_{1,1} := \frac{C_1}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o} - \frac{(\mathbf{a} - 1)^{0.5}}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o \cdot \mathbf{a}} - Cap_{1,2}$$

$$Cap_{N,N} := Cap_{1,1}$$

$C_n =$	$K_{nn, nnn+1} =$
0.709	1.216
1.987	1.597
2.871	1.847
3.186	1.847
2.871	1.597
1.987	1.216
0.709	

$Cap_{n,n} =$	$Ind_{n,n} =$	$Cap_{nnn, nnn+1} =$
1.370	11.223	0.730
5.876	4.005	0.193
8.590	2.772	0.254
9.555	2.497	0.294
8.590	2.772	0.294
5.876	4.005	0.254
1.333	11.223	0.193
		0.730



Simulation Results

To test the calculations I have run a simulation on ADS for $N = 7$, Return Loss = 30dB, $Z_0 = 50\Omega$.

You can see the results are in reasonable agreement. The ripple and return loss (S11) are better in the simulation. The bandwidth is excellent.

